Status of Studies on Algorithms for J/Ψ and Υ Level-2 Trigger

STAR

Manuel Calderon, TU, Trigger Workshop LBL, May 2002

- this talk was originally meant for a round the table discussion
- not a plenary talk but "work in progress"
- discussion during this meeting $\Rightarrow$ input for further studies

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Introduction

Goal: develop and test L2 algorithm for triggering on Quarkonia in STAR, i.e. for triggering on mass

Assumptions:

- Input into L2: EMC, BBC, ZDC
- Input data are pedestal subtracted and gain corrected

Requirements:

- Fast (< 1 ms) and robust (not fancy) algorithm
- Evaluate invariant mass of candidates on event

Approach:

- Simple (Mickey Mouse MC) simulation for proof of principle before more elaborate and detailed studies

Open Questions:

- EMC granularity (tower or trigger patch 4×4) ⇒ study both
- EMC Energy resolution ⇒ study for 17%/√E to 50 %/√E
- Vertex-z resolution (BBC/ZDC/both) ⇒ study 1, 5, and 10 cm

Simulations: Input Distributions

Simple parametrization from ALICE tuned for 200 GeV at RHIC:

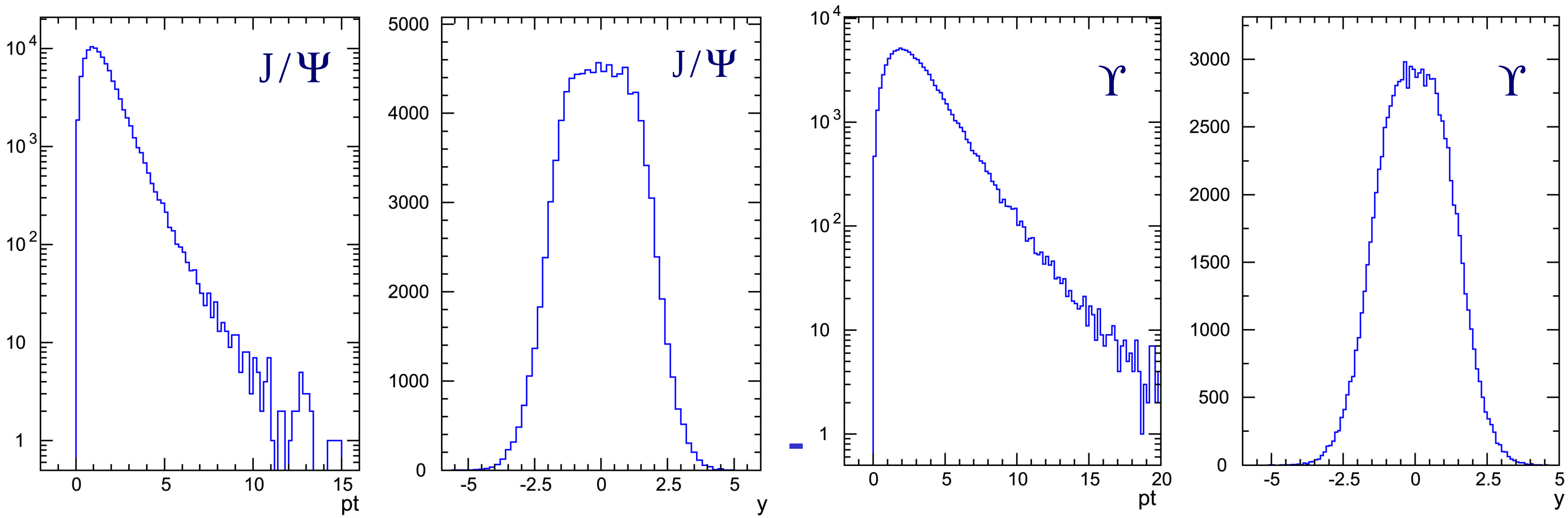
$$\frac{ds}{dp_T} = \frac{p_T}{[1+(p_T/p_0)^2]^{3.5}}$$

$$\frac{ds}{dy} = \begin{cases} 1 & \text{for } y < y_0 \\ \exp[-(y-y_0)^2/2] & \text{for } y > y_0 \end{cases}$$

$J/\Psi:\quad p_0 = 2.3, y_0 = 1.0$

$\mathrm{Y}:\quad p_0 = 4.7, y_0 = 0.5$

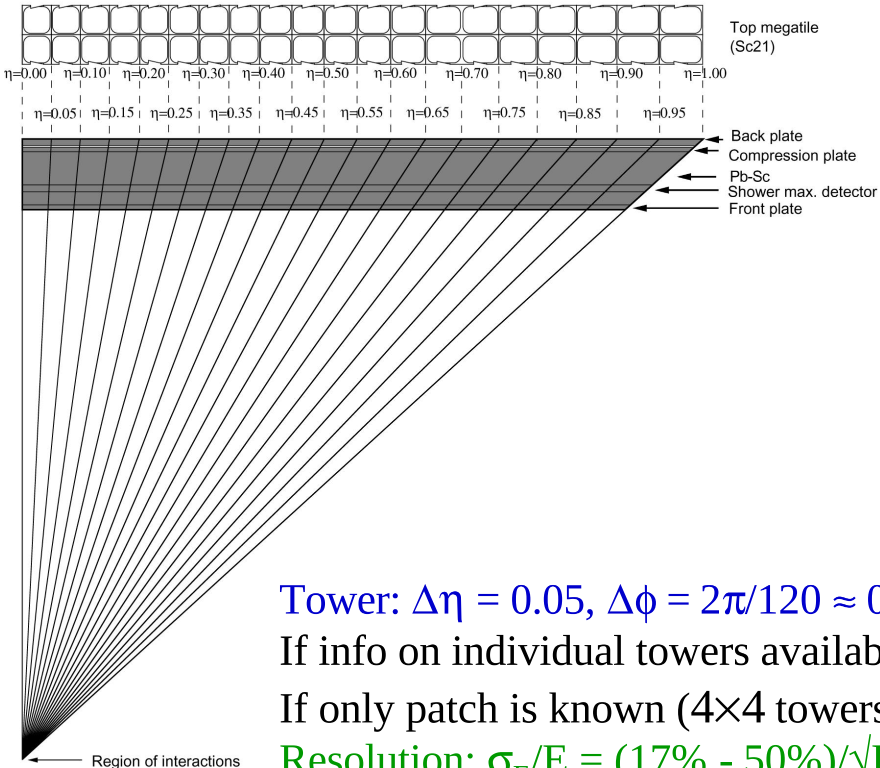
Very close to predictions from D. Kharzeevs

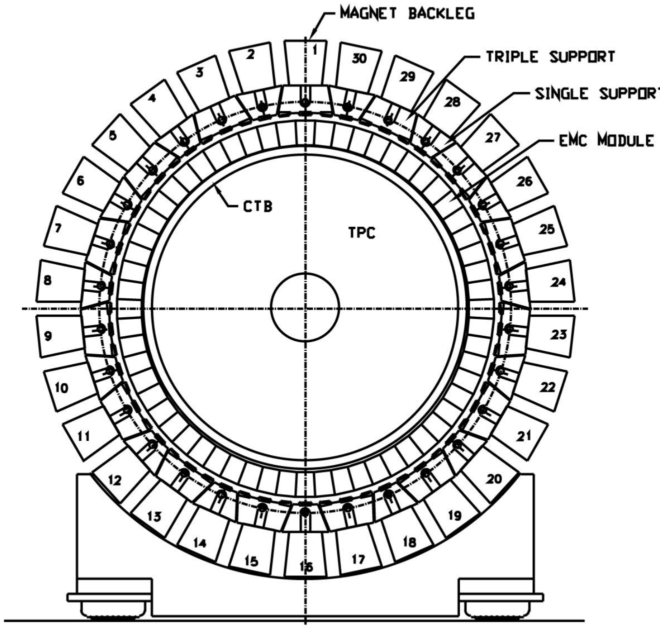


Simulation: Strategy

- Generation
  - Generate J/Ψ (Υ) $\Rightarrow$ p_T and y
  - Decay into e^+e^- $\Rightarrow$ p^e_T and y^e
  - Assume vertex (0,0,0)
  - Generate helices for electron and positron for full field
  - Check for intersection with full (half) EMC barrel
- Smearing
  - Smear vertex according to BBC/ZDC vertex resolution
  - Smear position of intersection with EMC
  - Smear energy (since E/p = 1 is assumed $\Rightarrow$ smeared p)
- Reconstruction
  - Given $(x,y,z)_{vertex}$, two $(x,y,z)_{point\text{-}EMC}$ and p_1, p_2 $\Rightarrow$ mass

Simulations: Smearing





Tower: $\Delta\eta = 0.05$, $\Delta\phi = 2\pi/120 \approx 0.054$

If info on individual towers available $\Rightarrow$ assume pos = tower center

If only patch is known (4×4 towers) $\Rightarrow$ assume pos = patch center

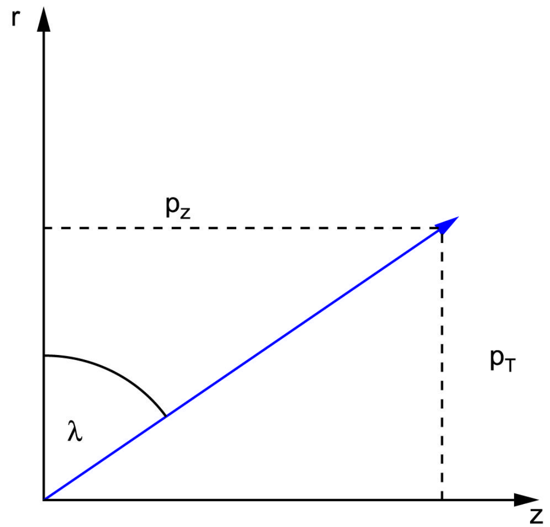
Resolution: $\sigma_E/E = (17\% - 50\%)/\sqrt{E}$?

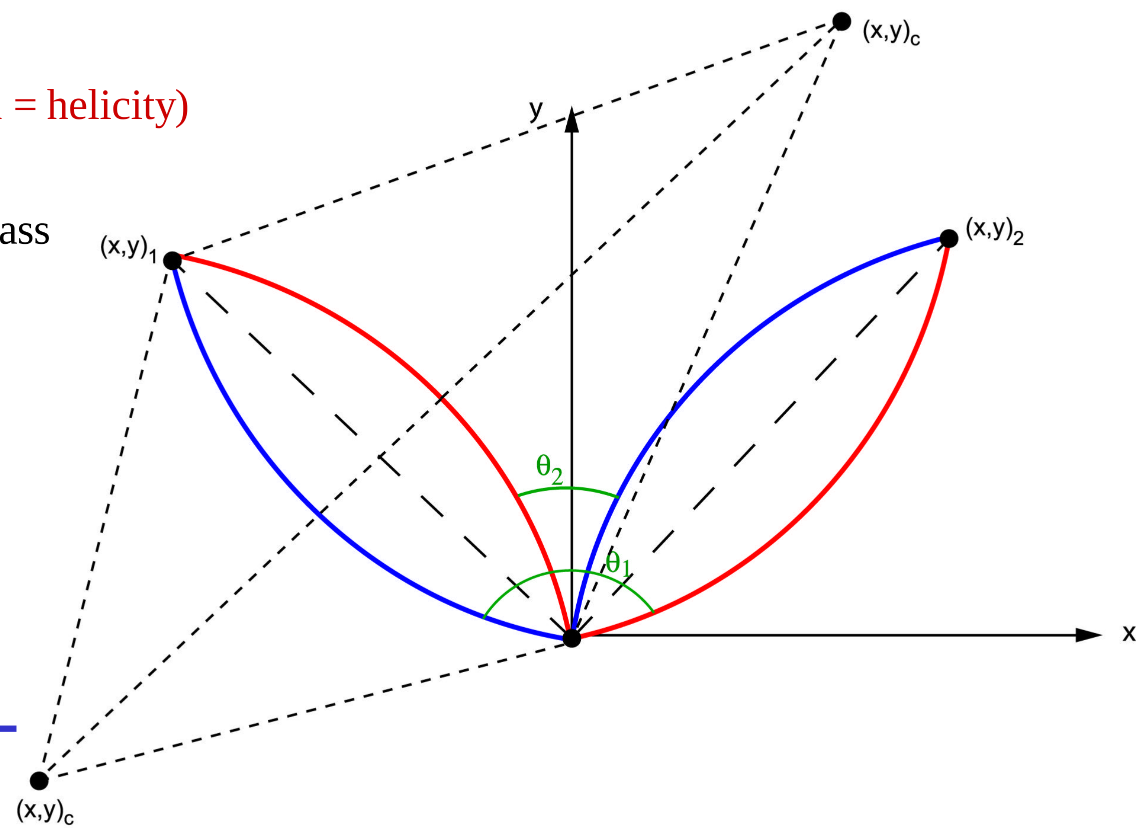
Vertex: ZDC for central events $\Delta z \approx 10$ cm, for min bias 6 cm
BBC with improvements 5 cm ?
Combine ZDC+BBC?

Reconstruction: Approach I (e^+ e^- ambiguity)

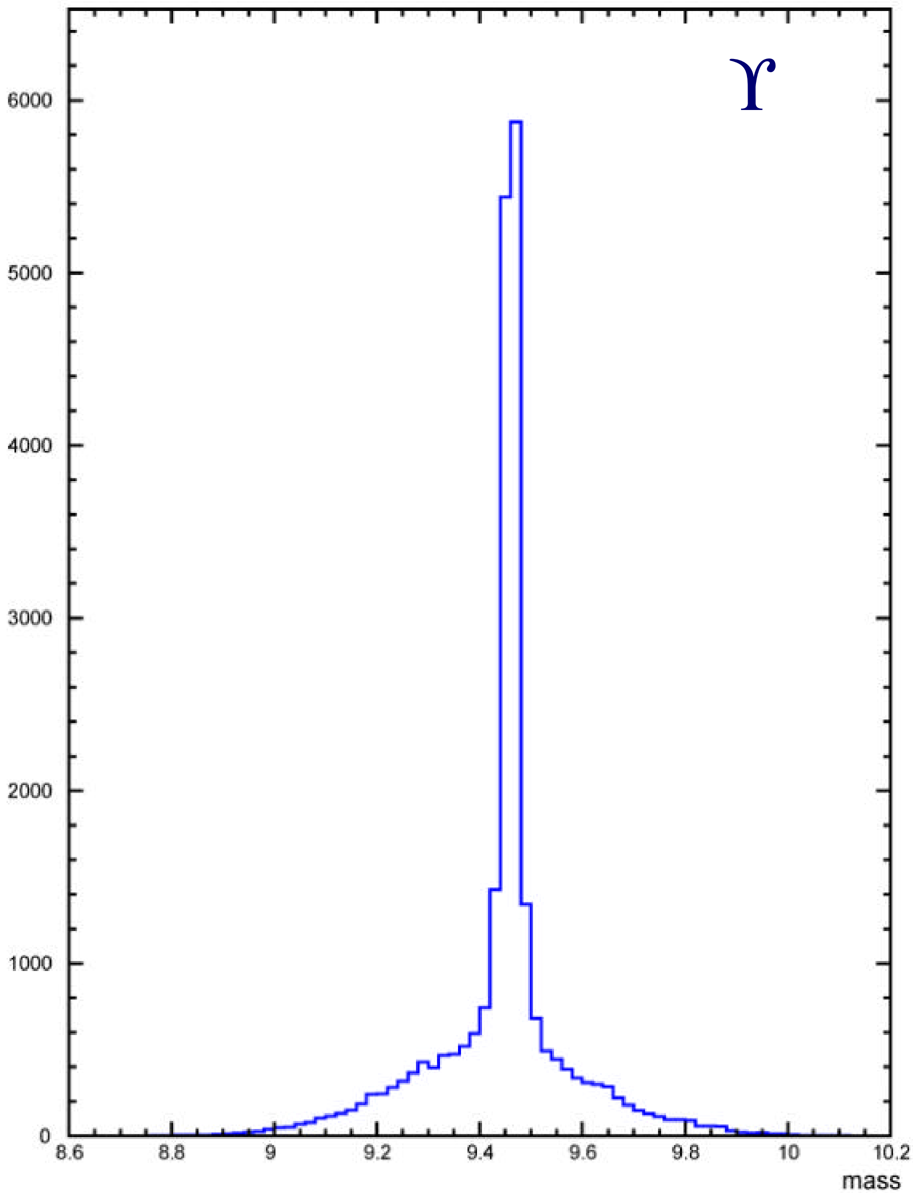
Electron track:

- $p = (E_{EMC}{}^2 - m^2)^{½} \approx E_{EMC}$
- $\tan\lambda \approx p_z/p_T$ (approximation only : sagitta $\Leftrightarrow$ pathlength)
- $p_T = p/(1+\tan^2\lambda)^{½}$
- $p_z = p_T \tan\lambda$
- $R = p_T/(B\ c)$
- $R \Rightarrow (x,y)_c$ ambiguous!
- phase $\phi_0 = \mathrm{atan}((y_0 - y_c)/(x_0 - x_c))$
- Azimuthal angle $\Psi = \phi_0 + h\ \pi/2$ (h = helicity)
- Finally: $\Psi \Rightarrow p_x$ and p_y
- Same for other track $\Rightarrow$ invariant mass





Reconstruction: Approach I (continued)



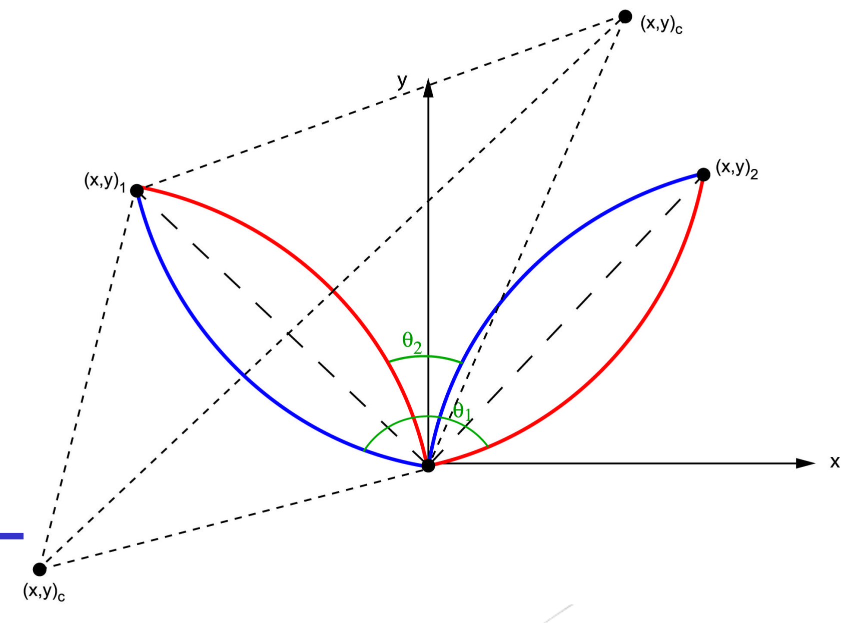
⇐ Example for ϒ without smearing

Should be delta function

Cons:

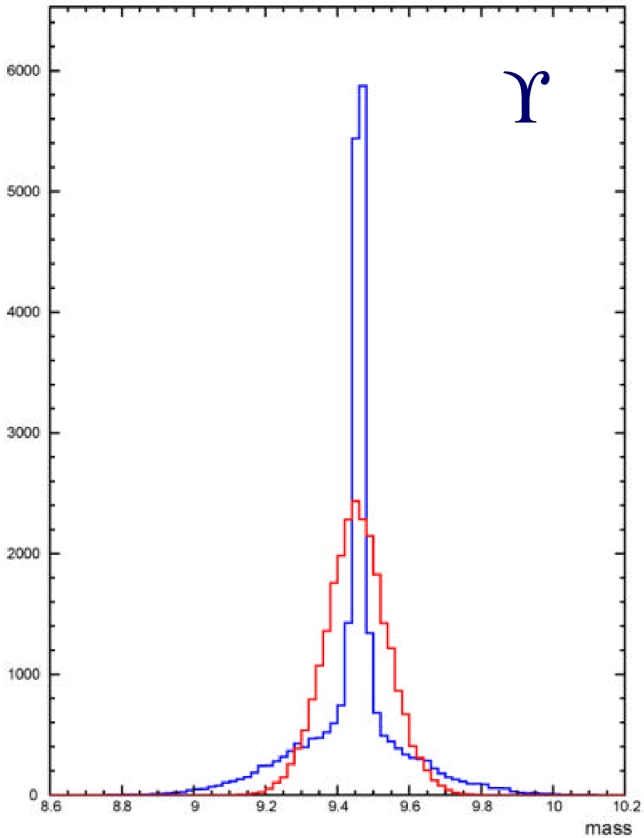
- half of the time right half wrong
- very elaborate and costly (CPU) lots of trigonometry

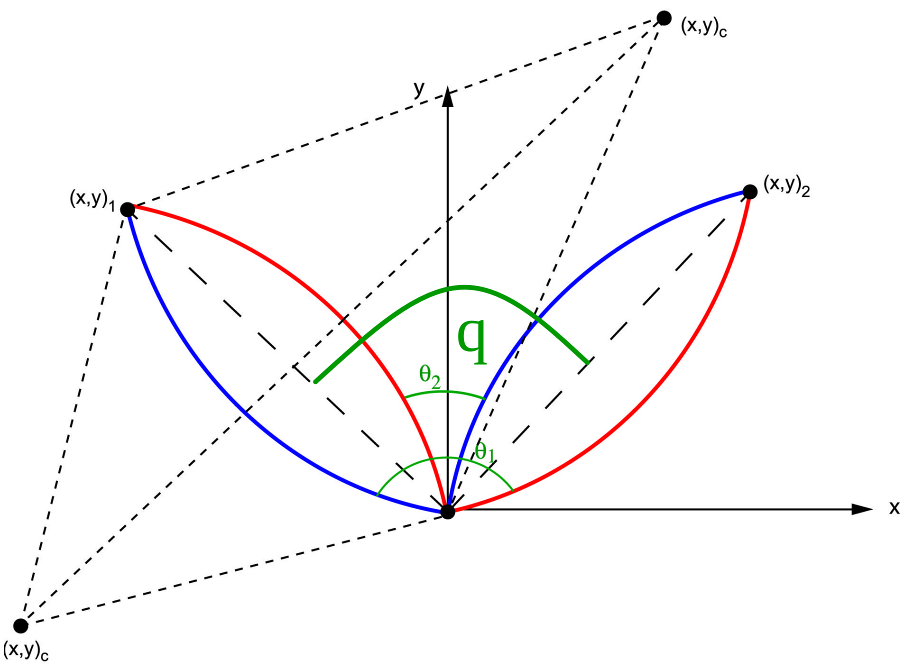
Problem with sign doesn't play a role for like-sign pairs



Reconstruction: Approach II (quick, dirty and good)

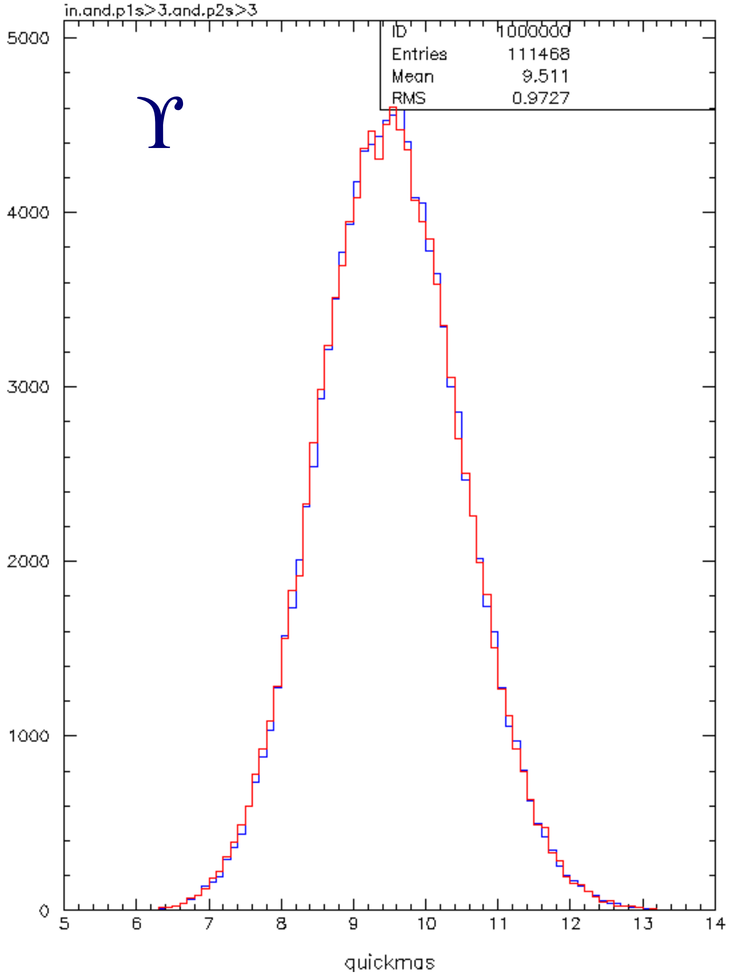
- $p_1 = (E_{EMC-1}{}^2 - m^2)^{½} \approx E_{EMC}$
- $p_2 = (E_{EMC-2}{}^2 - m^2)^{½} \approx E_{EMC}$
- $\cos\theta = x1 \cdot x2/(|x1|\ |x2|)$
- $m^2 \approx 2\ p_1\ p_2\ (1 - \cos\theta)$





Pro:
- simple, fast (no trig function)
- avoids ambiguity

Comparison: Approach I vs. II



⇐ Example for ϒ with smearing (tower, 34%, 10cm)
blue = approach II (quick and dirty)
red = approach I (elaborate)

Simpler approach sufficient for more realistic cases

Same is true for J/Ψ

L2 Algorithm: resolution for J/Ψ

	Exact	Tower	Patch (4×4)
sigma_z = 0 σ_{EMC} = 0%	142 249	145 257	175 384
sigma_z = 1 cm σ_{EMC} = 17%	288 315	289 324	304 433
sigma_z = 5 cm σ_{EMC} = 17%	289 316	290 325	304 433
sigma_z = 10 cm σ_{EMC} = 17%	292 321	293 328	307 435
sigma_z = 1 cm σ_{EMC} = 34%	476 522	477 528	486 605
sigma_z = 5 cm σ_{EMC} = 34%	477 521	478 527	486 604
sigma_z = 10 cm σ_{EMC} = 34%	479 523	480 529	488 604
sigma_z = 15 cm σ_{EMC} = 50%	644 819	645 823	651 867

$P_e > 1.5$ GeV/c

$P_e > 3$ GeV/c

All values in MeV, σ_{EMC} means $\sigma_E/E = \sigma_{EMC}/\sqrt{E}$, Gaussian smearing

L2 Algorithm: resolution for Υ

	Exact	Tower	Patch (4×4)
sigma_z = 0 σ_{EMC} = 0%	87	98	203
sigma_z = 1 cm σ_{EMC} = 17%	504	506	534
sigma_z = 5 cm σ_{EMC} = 17%	508	510	538
sigma_z = 10 cm σ_{EMC} = 17%	520	522	550
sigma_z = 1 cm σ_{EMC} = 34%	965	966	980
sigma_z = 5 cm σ_{EMC} = 34%	967	968	982
sigma_z = 10 cm σ_{EMC} = 34%	973	974	987
sigma_z = 15 cm σ_{EMC} = 50%	1355	1356	1365

All values in MeV, σ_{EMC} means $\sigma_E/E = \sigma_{EMC}/\sqrt{E}$, Gaussian smearing, $p_e > 3$ GeV/c

What goes into L2: Rates for J/Ψ

Assume:

(red) for half EMC

- Nominal Liminosity: $L = 0.2\ mb^{-1}\ s^{-1}$ $(= 2 \cdot 10^{6}\ cm^{-2}\ s^{-1})$
- EMC/L2 rate = 1kHz

p_e cut [MeV]	acceptance ε [%]
0	19.8 (5.4)
1.5	7.5 (1.5)
2	1.4 (0.5)
3	0.1 (0.05)

Table 1.

J/Ψ:

- $\sigma^{AA} = A^{2\alpha}\ \sigma^{pp} = 10.7$ mb for $\Delta y=1$ and $\alpha = 0.92$
- Rate: $10.7\ mb \cdot 0.2\ mb^{-1}\ s^{-1} \cdot BR(0.06) = 0.13$ Hz
- for $\Delta y \rightarrow$ full phasespace: 4.5
- Both in acceptance of EMC: → see Table 1
- Min Bias:
  - $7200\ mb \cdot 0.2\ mb^{-1}\ s^{-1} = 1440$ Hz
  - sampling: 1000/1440 = 0.7 (deadtime?)
  - L2 rate: $0.13\ Hz \cdot 0.7 \cdot 4.5 \cdot \varepsilon \rightarrow$ see Table 2
- 10% Central
  - $720\ mb \cdot 0.2\ mb^{-1}\ s^{-1} = 144$ Hz
  - sampling = 1 → no loss
  - L2 rate: $0.13\ Hz \cdot 0.4 \cdot 4.5 \cdot \varepsilon \rightarrow$ see Table 2

p_e cut [MeV]	min bias [Hz]	10% central [Hz]
0	$8.2 \cdot 10^{-2}$	$4.7 \cdot 10^{-2}$
1.5	$3.1 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$
2	$6 \cdot 10^{-3}$	$3 \cdot 10^{-3}$
3	$4 \cdot 10^{-4}$	$2 \cdot 10^{-4}$

Table 2.

No trigger: min bias ~ 30/1M events; 10% central ~ 120/1M events (p_e > 1.5 GeV/c)

What goes into L2: Rates for Υ

Assume:

- Nominal Liminosity: $L = 0.2\ mb^{-1}\ s^{-1}$ (= $2 \cdot 10^{6}\ cm^{-2}\ s^{-1}$)
- EMC/L2 rate = 1kHz

Υ:

- $\sigma^{AA} = A^{2\alpha} \cdot \sigma^{pp} \cdot BR = 1.7\ \mu b$ for $\Delta y=1$ and $\alpha = 0.92$
- Rate: $1.7\ \mu b \cdot 0.2\ mb^{-1}\ s^{-1} = 3.4 \cdot 10^{-4}$ Hz
- for $\Delta y \rightarrow$ full phasespace: 3.5
- Both in acceptance of EMC: $\rightarrow$ see table 1
- Min Bias:
  - $7200\ mb \cdot 0.2\ mb^{-1}\ s^{-1} = 1440$ Hz
  - sampling: 1000/1440 = 0.7
  - L2 rate: $3.4 \cdot 10^{-4}\ Hz \cdot 0.7 \cdot 3.5 \cdot \varepsilon \rightarrow$ see table 2
- 10% Central
  - $720\ mb \cdot 0.2\ mb^{-1}\ s^{-1} = 144$ Hz
  - sampling = 1 $\rightarrow$ no loss
  - L2 rate: $3.4 \cdot 10^{-4}\ Hz \cdot 0.4 \cdot 3.5 \cdot \varepsilon \rightarrow$ see table 2

(red) for half EMC

p_e cut [MeV]	acceptance ε [%]
0	24.9 (6.9)
1.5	24.8 (6.8)
2	24.7 (6.8)
3	23.3 (6.6)

Table 1.

p_e cut [MeV]	min bias [Hz]	10% central [Hz]
0	$2.1 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$
1.5	$2.1 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$
2	$2.1 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$
3	$1.9 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$

Table 2.

No Background Simulations (yet)

Needs realistic simulations:

Mickey-Mouse MC not the right tool – need full simulation

Look at background using 2001 data (see T. Dietel)

On the positive side:

- Energy scale moves up by p/E

But ...

- occupancy, pile-up, noise
- photons, other physics background

Q:

- what can be done at **L2 level** to reject single hadrons (assume all tower data available?)

For L3: L2 needs to achieve a rate reduction factor of

- 10 (min bias)
- 3 (central)

If this can be achieved with a reasonable threshold depends solely on the background

Summary & ToDo List

Simple algorithm sufficient to derive invariant mass J/Ψ and ϒ

- crucial: energy resolution
- less crucial: vertex-z position and granularity
  - however granularity ⇔ energy resolution
- To get a reasonable J/Ψ sample we cannot cut much higher than 1.5 GeV
  - downside drives background up, worse E resolution
- Half EMC cost between 3-5 loss in rate (p cut dependent)
- ϒ not possible with half EMC and current RHIC performance
  - 3 GeV cut gets them (almost) all
  - algorithm: different E cuts for different mass regions possible but probably not necessary (clean around m=9 GeV ?)

Todo:

- Geant + L2 simulations (EMC response)
  - realistic constraints (tower, patch, ...)

Q:

- Assume it works: what bandwidth is STAR willing to allocate for hard probes and Quarkonia?
  - last years few % won't work